

## THE AERODYNAMIC RESISTANCES DETERMINED BY THE ROLLING EQUIPMENT FOR THE ELECTRIC LOCOMOTIVE LE 060 EA 5100 KW

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*Depending of the construction of railway vehicle engine, the equipment of traction and rolling may have a lower or higher influence about the running resistance. This article aims an analysis of the aerodynamic resistance generated by these equipments of the locomotive LE 060 EA of 5100kW. In order to estimate the values of aerodynamic resistances generated by this equipments it was modeled geometric in 3D at 1:1 scale the chassis, the bogie frame and axle engines for locomotive. The ensemble obtained is used for simulation air flow on different values of speed of movement of the vehicle in the range of between 0km/h and 200km/h.*

**Keywords:** aerodynamic resistance, the rolling and traction equipment, air flow simulation.

### 1. Introduction

The aerodynamic forces generated by rolling equipment have a wide enough range of variation determinate in particular by the type of vehicle. To illustrate this point, in case high-speed trains compared to the case of classic train (consisting of the motor vehicle and towed vehicle) it can be seen that the total aerodynamic resistance values are lower by about 50% [1]. For reference, all these data refer to the same train length (200 m). [1]

In the case of the classical trains consisting of locomotives and wagons (where are not hulls or skirts to hide the rolling equipment), the aerodynamic resistances generated by these equipment can reach values of 40% - 60% from total value of running resistance of the respective vehicle. [1, 2]

Generalized formula for determining the running resistance for railway vehicles is known as Davis's relationship [3-7]:

$$R_t = A + B \cdot v + C \cdot v^2 \quad (1)$$

Where  $R_t$  – total running resistance of the vehicle,

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$A$  – mechanical rolling resistances caused by the loads on axle,

$B \cdot v$  – non-aerodynamic running resistances,

$C \cdot v^2$  – aerodynamic running resistances;  $v$  – speed of moving for vehicle;

According works [8-11], values Davis's coefficients for LE 060 EA of 5100kW locomotive are:  $A= 1500$  N;  $B=12$  N/(km/h);  $C=0,3$  N/(km/h)<sup>2</sup>.

Explicit formula for the parameter "C" regarding aerodynamic resistances according to the literature [12, 13], is:

$$C = \frac{C_x \cdot S \cdot \rho}{2} \quad (2)$$

Where:  $C_x = \frac{2 \cdot F_x}{S \cdot \rho \cdot \bar{v}^2}$  – aerodynamic coefficient of air sliding (also known as the

coefficient of air penetration),

$S$  – front surface of the vehicle in cross section (m<sup>2</sup>),

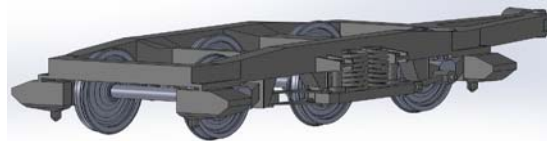
$\rho$  – density of the moving vehicle air (kg/m<sup>3</sup>),

$F_x$  – the frontal aerodynamic resistances force (N),

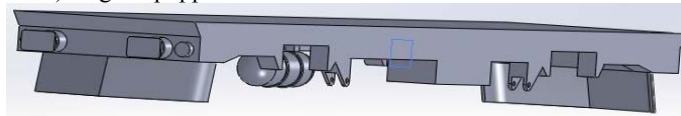
$\bar{v}$  – velocity of the fluid (air) (m/s).

## 2. Simulation of air flow through the equipment of under the vehicle structure

For the analysis we considered the situation caused by the rolling equipments of the LE 060 EA of 5100kW locomotive. First, we modelled geometric in 3D at scale 1: 1 rolling equipments consists by: axle, bogie frame, chassis and suspension elements through which these elements are interconnected using Autodesk Inventor Fig. 1.



a) Bogie equipped of the locomotive LE 060 EA of 5100kW



b) The chassis of the locomotive LE 060 EA of 5100kW



c) The assembly, chassis and bogies of the locomotive.

Fig. 1 The model rolling equipment of the LE 060 EA of 5100 kW locomotive at scale 1: 1

In order to simulate air flow we considered six cases in which the vehicle is moving at a constant speed in the range 0km/h – 200km/h (10m/s, 20m/s, 30m/s, 40m/s, 50m/s, 55m/s).

The delimitation of the volume regarding air flow is managed as follows:

- in vertical plan we considered an appropriate plan the wheel tracks of vehicle, and another plane located 6.5 m from it;
- for transverse section, we considered two plans located symmetrically at 6 m from the longitudinal plane of the vehicle;
- The longitudinal section, we considered two planes located at 13 m and 18 m from the transverse plane of frame.

First plan of longitudinal sections (13 m) corresponds to the front part of the locomotive in air flow direction and the second plan of sections part (18m) at the back of the vehicle Fig. 2.

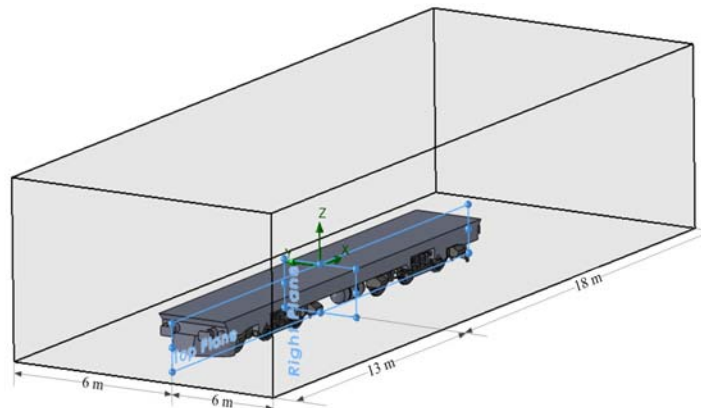
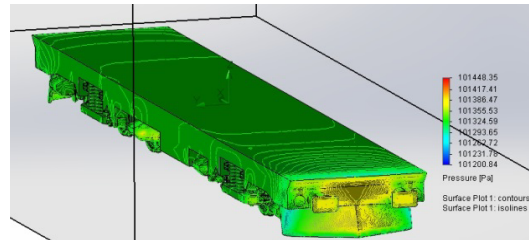


Fig. 2 The air flow volume considered

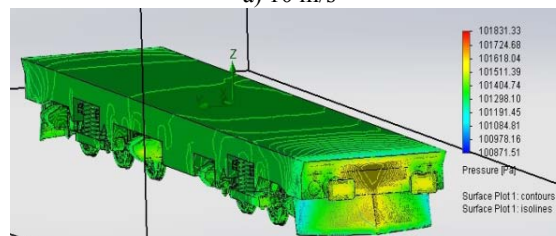
As input parameters regarding atmospheric conditions, we considered the values: 101325 Pa for pressure and 293.2 K for temperature.

By simulating air flow, is allowed determination of the pressures exerted on rolling equipment, dynamic pressure of air and aerodynamic resistances for the 6 modes analysed.

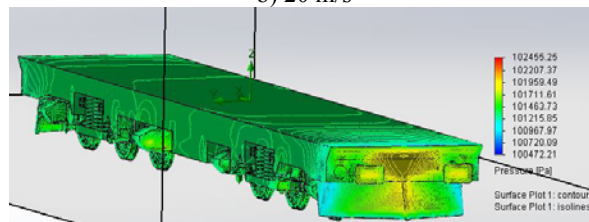
In the Fig. 3 and Fig. 4 is showed the distribution of pressure on the rolling equipment respective, the contour lines of pressure obtained under dynamic simulations.



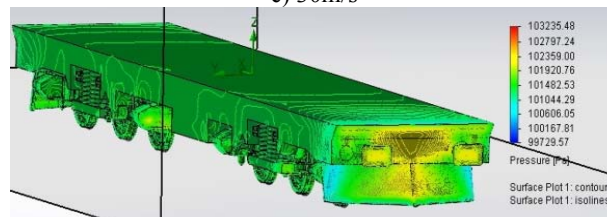
a) 10 m/s



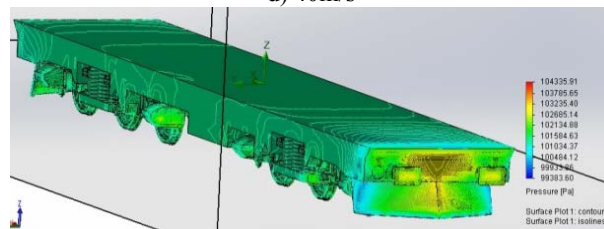
b) 20 m/s



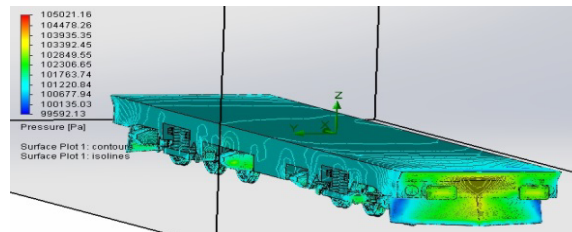
c) 30m/s



d) 40m/s

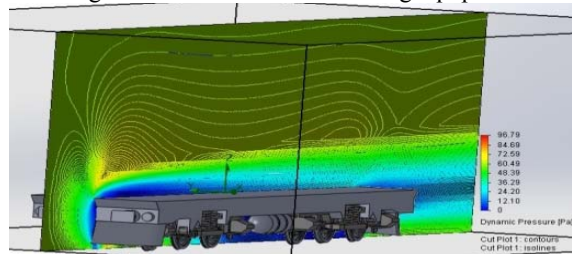


e) 50m/s

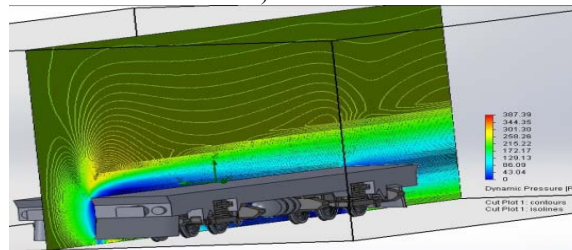


f) 55m/s

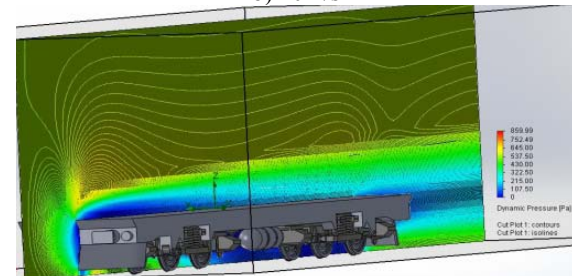
Fig. 3 Pressures exerted on rolling equipment



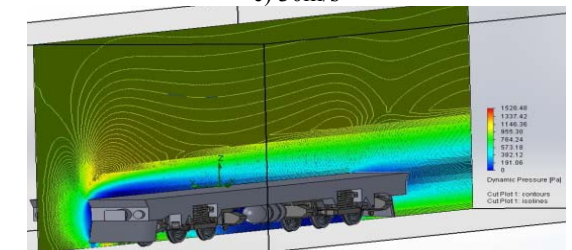
a) 10 m/s



b) 20m/s



c) 30m/s



d) 40m/s

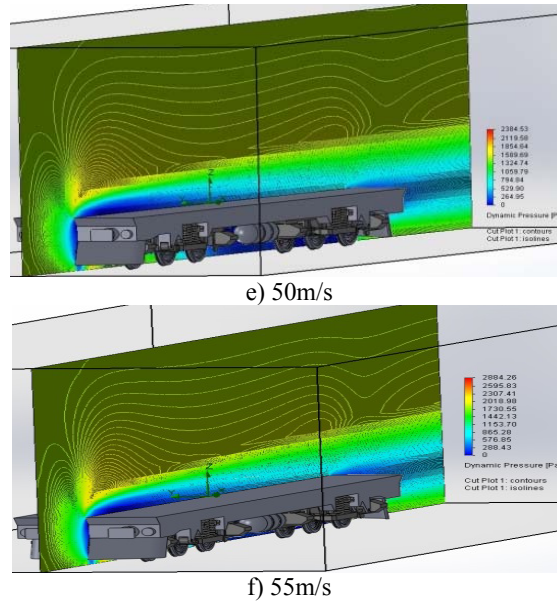


Fig. 4 Contour lines of the dynamic pressure of the air in the median longitudinal plane of the vehicle

The variation of the aerodynamic resistance generated by the rolling equipments obtained during the simulation flow of air, taking into account six values for speed of analysed vehicle are shown in Fig.5.

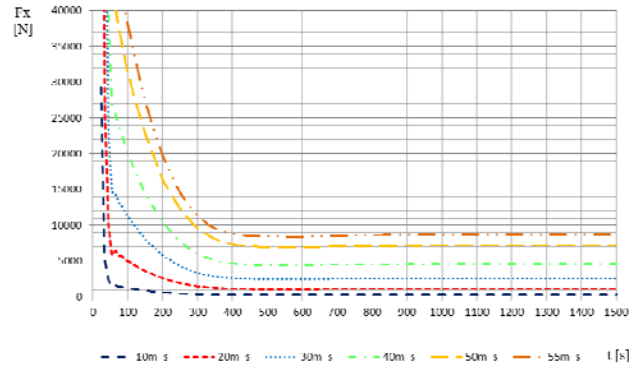


Fig. 5 Aerodynamic resistances obtained by simulation rolling equipment

Stabilized values of aerodynamic resistance caused by rolling equipment resulting from the simulations are presented in Table 1.

Table 1

Stabilized values of aerodynamic resistance of the rolling equipment ( $F_x$ [N]).

$v$ [m/s]	10	20	30	40	50	55
$F_x$ [N]	289,78	1156,52	2614,70	4635,84	7254,86	8803,10

The superposition of the running resistance of the locomotive over fixed values of aerodynamic resistance caused by rolling equipment is shown in Fig. 6. By reporting this final size at the first is obtained an estimate of the influence that the rolling equipment has in total resistance of the locomotive Fig.7

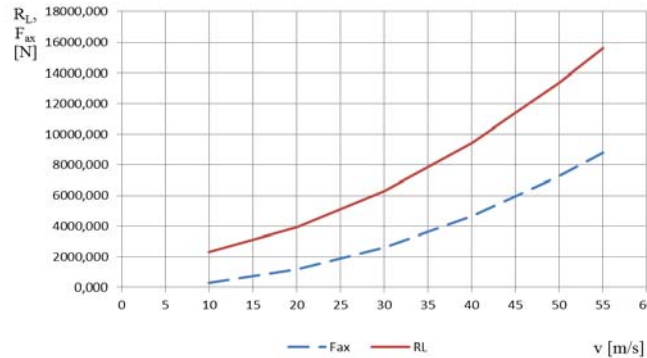


Fig. 6 Total running resistance of locomotive and rolling equipment aerodynamic obtained from simulation

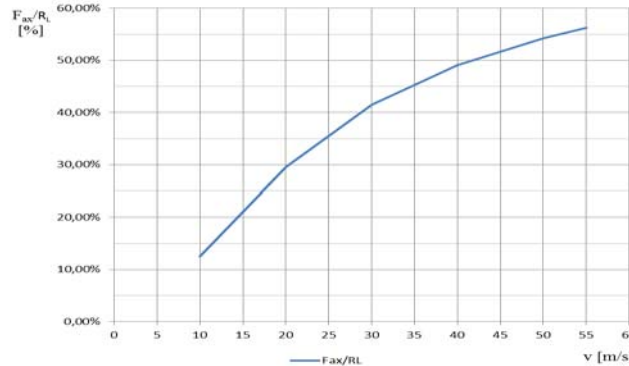


Fig. 7 The percentage of influence of aerodynamic resistance for rolling equipment from the total value of resistance

### 3. Conclusions

As can be seen from Fig. 3, increasing the speed of the vehicle determines, implicitly increasing pressure exercised on the rolling equipment for locomotive analyzed. At the same time dynamic air pressure values will have the same growth trend with vehicle speed as seen in Fig. 4.

Regarding the aerodynamic resistance of the rolling equipment, they have the same characteristic as the pressure once with increases of moving speed.

From Fig. 6 and Fig. 7 it can be seen that the influence it has rolling equipment, on the total running resistance is one significant that at speeds of about 200km / h get to at values of over 55%.

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### REFERENCES

- [1]. *R. S. Raghunathan, H.-D. Kim, T. Setoguch*, Aerodynamics of high-speed railway train. Progress in Aerospace Sciences, no. 38 (Issues 6–7), pp. 469–514, (2002)
- [2]. *Marius Spiroiu*, Tehnica marilor viteze în transportul feroviar, (Technology high speeds in railway) Bucuresti, Ed. MatrixRom (2012). (in Romanian)
- [3]. *S. Arsene, I. Sebesan*, Analysis of the resistance to motion in the passenger trains hauled by the locomotive LE 060 EA 5100kW, INCAS BULLETIN, Volume 6, Issue 3, pp. 13 – 21, (2014).
- [4]. *S. Arsene*, Analysis regarding the aerodynamic resistances on boxes electric locomotives, The International Conference on Innovation and Collaboration in Engineering Research – INCER-2013, Bucharest, pp. 157-160, (2013).
- [5]. *I. Sebeșan, B. Tarus*, Some aspects regarding the impact of aerodynamics on fuel consumption in railway applications. U.P.B. Sci. Bull., Series D, Vol. 73(Iss. 4), pp. 237-246, (2011).
- [6]. *S. Arsene, I. Sebeșan, G. Popa*, The influence of wind on the pantograph placed on the railway electric vehicles bodywork. Procedia - Social and Behavioral Sciences, Vol. 186, pp. 1087–1094, (2015).
- [7]. *S. Arsene, I. Sebeșan, A. Certan, G. Popa*, Influence resistance at advancing on fuel consumption for vehicles that use an internal source of energy. Procedia - Social and Behavioral Sciences, Vol. 186, pp. 573 – 581, (2015).
- [8]. *S. Arsene*, Teză de Doctorat - Contribuții privind îmbunătățirea performanțelor de tracțiune ale vehiculelor electrice (Contributions to improve the performance of electric vehicle traction), Universitatea Politehnica din București, (2013). (in Romanian)
- [9]. *G. Chiriac*, Teză de Doctorat - Contribuții la utilizarea rațională a energiei de mișcare a vehiculelor (Contributions to the rational use of energy by the movement of vehicles), UNIVERSITATEA TEHNICA „GH. ASACHI”, IASI, (2002). (in Romanian)
- [10]. *I. Sebesan, S. Arsene, C. Stoica*, Experimental study on determination of aerodynamic resistance to progress for electric locomotive LE 060 EA1 of 5100 kW, Scientific Bulletin-U.P.B. Sci. Bull., Series D, 75(4), pp. 85-96, (2013).
- [11]. *S. Arsene, I. Sebesan*, Analysis of the resistance to motion in the passenger trains hauled by the locomotive LE 060 EA 5100kW, INCAS BULLETIN, Volume 6, Issue 3, pp. 13 – 21, (2014).
- [12]. *L. LI, W. Dong, Y. Ji, Z. Zhang*, A minimal-energy driving strategy for high-speed electric train. J Control Theory, 10(3), pp. 280–286, (2012).
- [13]. *F. Cheli, F. Ripamonti, D. Rocchi, G. Tomasini*, Aerodynamic behaviour investigation of the new EMUV250 train to cross wind, Journal of Wind Engineering and Industrial Aerodynamics, Volume 98(Issues 4–5), pp. 189–201, (2010).